FINAL REPORT

on

DIFFUSION IN SOLIDS

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by

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INTRODUCTION

The research done under this grant has involved a continuation of studies on grain-boundary diffusion and the initiation of an investigation of surface diffusion. Previous investigations studied the diffusion of nickel into copper bicrystals,[1] while the present experiments have been concerned with the diffusion of gold into copper bicrystals. The theoretical solutions and approximations were evaluated mathematically and the results used for the analysis of the experimental data. The case of surface diffusion in metal systems is comparable to that of grain-boundary diffusion in that both involve concomitant volume diffusion. Therefore experimental and theoretical studies of surface diffusion were initiated as an extension of those on grain-boundary diffusion.

RESEARCH PROGRESS

Completed Studies

An experimental study of gold diffusion into high-angle copper bicrystals was carried out, employing the boundary conditions of a continuous[2] and an instantaneous source.[3] It was found that for a continuous source, the grain-boundary diffusion parameter is not constant, as assumed in theoretical solutions, but decreases with increasing concentration of solute. A contribution due to surface diffusion was also observed in the instantaneous-source case. The results have been published in a paper entitled:

> "Grain-boundary Diffusion of Gold into Copper" by A. E. Austin and N. A. Richard, Journal of Applied Physics, Vol. 33 pp. 3569-3573, December, 1962.

An evaluation was made of theoretical solutions of the grain-boundary diffusion problem[2] by computation for a range of parameters appropriate to existing and contemplated experimental conditions. The ranges of validity of various approximate solutions were defined substantially more accurately than has been done previously. The results of this phase of the investigation were published in a paper entitled:

> "Theoretical Solutions of Grain-Boundary Diffusion Problem" by Van E. Wood, A. E. Austin and F. J. Milford, Journal of Applied Physics, Vol. 33, pp. 3574-3579, December, 1962.

Surface Diffusion Experiments

The analyses of surface diffusion and grain-boundary diffusion are similar in that account must be taken of the simultaneous volume diffusion. There may be various boundary conditions similar to those involved in grain-boundary diffusion. These include the continuous source[2], an instantaneous

source(3), or a finite limited source.(4) In the case of surface diffusion there may be a dependence of rate upon the surface orientation, direction of diffusion and surface impurities.

To examine these factors, experiments have been devised for the study of the diffusion of one metal upon the surface of another metal. These involve the deposition and diffusion of a thin source of defined size on a clean surface of a single crystal of known orientation. The resulting solute surface and lattice concentrations are to be measured by electron-probe microanalysis of the free surface and of cross-sections. Ultra-high vacuum experimental conditions (10^{-9} to 10^{-10} Torr) were chosen, in order to provide control of surface impurities. An ultra-high vacuum system has been constructed to permit the heat-treatment of the metal crystal before and after deposition of a source by evaporation. The system was made of stainless steel with copper shear gaskets, ion pumps and high-vacuum valves to permit bake-out up to 450 C. The desired vacuum of 10^{-10} Torr after bake-out has been obtained. The internal filament heaters and baffle assemblies for evaporation and heat-treatment of the metal crystal were constructed. Initial experiments have been performed on the control of the source size for gold evaporation onto copper.

Studies in Progress

It is planned to continue the study of surface diffusion of gold on copper crystals. Theoretical solutions for other boundary conditions involving surface diffusion will be sought, particularly in regard to the possibility of directional dependence of diffusion on a single crystal surface.

REFERENCES

1. A. E. Austin, N. A. Richard, Journal of Applied Physics 32, 1462(1961).

2. R.T.P. Whipple, Phil. Mag. 45, 1225(1954).

3. T. Suzuoka, Trans. Japan Inst. of Metals 2, 25(1961).

4. V. G. Lozovik, Ukranian Journal of Physics 3, 464(1958).

PERSONNEL

The personnel contributing to this research were: Dr. A. E. Austin, Dr. Van E. Wood, Dr. F. J. Milford and Mr. N. A. Richard.

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